

# TRUE DTMF DIALER

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

5           This invention relates generally to dual tone multiple frequency (DTMF) generation. More particularly, it relates to a method and apparatus allowing a processor (e.g., a digital signal processor) to behave as though it is a true dialer capable of seamlessly intermixing keypad input and automatic dialing, without the need for direct access to a  
10   keypad.

### 2. Background of Related Art

          Digital telephone devices such as digital telephones and digital telephone answering devices have become commonplace. Such  
15   devices typically include a processor (e.g., a controller or microprocessor) for handling overall control of the telephone device, and another processor such as a DSP to handle time intensive tasks such as DTMF tone generation and/or detection.

          DTMF tones (i.e., touch tones) are typically used to  
20   communicate information, e.g., a telephone number, over a telephone line. At first, external DTMF generator circuits were used to generate touch tone signals. The external DTMF generation circuit has since been replaced in many applications with DTMF generation application software within the code of a digital signal processor (DSP).

25           Accordingly, DTMF generation has since become a standard feature on many DSPs. In the drive to minimize the bill of materials for a particular system, more and more telephony designers are looking at the DSP to replace expensive external DTMF generators/dialers in products where a DSP is an essential part of the design (e.g., in a telephone  
30   answering device and/or a digital speakerphone).

Although the integration of DTMF generation within a DSP has reduced hardware costs, it has caused a substantial amount of cost in the development and handling of software necessary to guarantee that stringent regulatory timing requirements for the transmission of DTMF tones be adhered to. Such timing requirements include the minimum length of each DTMF tone, and the minimum length of the pause between each transmitted DTMF tone.

However, due to the stringent timing requirements of DTMF dialing, what might start as an inexpensive solution has the potential of quickly turning into an implementation nightmare for software engineers.

Fig. 1 shows a conventional system utilizing a controller to pass information to a DSP to generate a specific one of the sixteen or so conventional DTMF tones. For instance, a controller **14** including a timer **14a** instructs a DSP **13** including a DTMF generator **11** to output a DTMF tone corresponding to a specific digit on a telephone line **12** through an appropriate telephone line interface **15** until instructed to stop. Thus, to dial a telephone number, the controller informs the DSP digit-by-digit to output DTMF tones corresponding to the telephone number.

Typically, the controller **14** communicates with the DSP **13** via a serial or parallel communication link. In this conventional system, the timing length of each DTMF tone signal, as well as the pauses between each DTMF tone signal, are controlled by the controller **14**.

To transmit a DTMF tone signal, the controller **14** sends DTMF signal instructions to the DTMF tone generator **11** in the DSP, e.g. a code from 1 to 16. The DTMF tone generator **11** then processes the instruction by generating an appropriate DTMF tone signal for transmission on the telephone line **12** via a codec (which may be integrated in the DSP **13** or may be external to the DSP **13**), and the telephone line interface **15**.

However, although the conventional DSP generates DTMF tones on a telephone line, because the DTMF tones are output digit-by-digit, the timing of the output DTMF tones is ultimately controlled by the controller. Thus, the controller is conventionally responsible for maintaining the minimum length of time for each DTMF tone output, and for maintaining a minimum pause time between each DTMF tone output.

The timing complexity in DTMF tone signal generation is illustrated in Fig. 2.

In particular, in step **201**, the controller **14** first receives data corresponding to a series of touch tone digits (e.g., a telephone number) from, e.g., a keypad, and transmits tone instructions to the DSP **13** based on the same.

In step **202**, the controller **14** instructs the DTMF tone generator **11** in the DSP **13** to start generation of a particular DTMF tone corresponding to a first digit in the touch tone data.

In conventional systems, the controller **14** determines the timing of the DTMF touch tone signals. Thus, in step **203**, the controller **14** determines if a minimum amount of time has elapsed, e.g., 100 milliseconds, to establish a minimum length of the DTMF tone signal.

After a sufficient amount of time has elapsed, the controller **14** instructs the DSP **13** to cease generation of the previously requested DTMF tone signal.

Step **206** determines if there are more digits in the touch tone data. If so, the process repeats, but with the controller **14** first ensuring that a minimum off time has elapsed as shown in step **205**.

Fig. 2 is shown in simplistic form. In particular applications, the DSP may acknowledge receipt of instructions from the controller **14**.

Thus, based on the particular timing requirements for the applicable region or country, the conventional controller **14** must determine and ensure a minimum timing, both as to the length of the

DTMF tone and as to the minimum pauses therebetween. Accordingly, conventional digital telephone systems have a timing complexity which is exacerbated by at least two factors. First, the controller may be busy processing other tasks while simultaneously determining the timing of generation of the DTMF signal instructions. Secondly, the DSP may be busy and therefore not be able to send an acknowledgment at the time that the controller determines that the next DTMF signal instruction should be sent, therefore requiring the instruction to be resent. Thus, using current technology, the use of a DSP for DTMF generation is complicated by the fact that either or both a DSP and a controller may be busy with other tasks at the time that the next DTMF tone transmission or tone stoppage should take place.

It would prove to be a fairly expensive item if all the DSP performed was DTMF tone generation. Thus, the DSP includes modules or other software to handle other tasks such as voice compression/decompression. Unfortunately, since the DSP is also used for functions other than generating DTMF, the DSP may be busy at the specific time that the controller desires a DTMF tone to be output.

The conventional controller may output a request to the DSP, then wait for confirmation that the tone is being output. Then, after a sufficient amount of time corresponding to a minimum length for DTMF tone transmission according to regulatory standards, the controller will again communicate with the DSP to request that the tone be stopped.

To avoid excessive wait cycles wherein the controller is merely waiting for the DSP to output a requested DTMF tone, the controller might merely output a DTMF tone request signal to the DSP on a periodic basis, e.g., every 100 millisecond, assuming that the DSP finally got to output the previously requested DTMF tone.

Unfortunately, control of DTMF tone output by one processor for output by another processor inherently includes timing 'jitter'

or differences between the length of each DTMF tone and the pauses therebetween, particularly as the workload and interrupt servicing of the DSP increases. Older systems utilizing external DTMF generators did not exhibit these timing differences because conventional DTMF generators were dedicated devices for generating the requested DTMF tones only.

Accordingly, while the microcontroller tries to maintain accurate and consistent digit/pause periods by sending timely start/stop DTMF generator commands to the DSP, often the resulting DTMF digits output to the telephone line do not comply with the regulatory requirements for accuracy and consistency. This is because the DSP is an independent device running independent software algorithms to the microcontroller and its readiness to receive commands as well as command execution speed vary depending on the current task being processed (e.g., background memory management, signal processing, etc.). The problem is worse still in PC telephony applications where the controlling software is unable to keep accurate timing due to the multi-tasking nature of PC processors.

Others have attempted to solve the timing problems associated with dialing using a processor input to a DSP by implementing a speed dial feature. In this implementation, much like a memory telephone, the processor is allowed to store several digit sequences into a reserved portion of random access memory (RAM) in the DSP, typically up to a defined maximum of, e.g., 16 digits for each digit sequence. Digit/pause timing is pre-programmed by the processor.

Using a single command such as "DIAL LOCATION 3", the processor generates accurate and consistent DTMF digit commands to DSP, which in turn generates the DTMF tones on the telephone line consistent with the timing set forth by the processor. Unfortunately, a problem with this solution is that it does not allow for the possibility of

manual dialing on a keypad where digits are dialed on the fly, at varying lengths.

There is thus a need for a method and apparatus to free the microprocessor from maintaining timing requirements with respect to dialing.

### SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, a tone dialer comprises a dial buffer adapted to contain a plurality of tone generator commands, and a tone generator adapted to generate tones in accordance with a sequence of the plurality of tone generator commands. The tone generator commands include a first command corresponding to a mimicked activation of a particular key, and a second command corresponding to a mimicked release of the particular key.

A method of digitally generating tones in accordance with another aspect of the present invention comprises inputting a plurality of tone commands into a dial buffer accessible by a first processor. A sequence of tone command information is output from the dial buffer to a tone generator. The output sequence of tone command information is sequentially presented to a tone generator. Tones are generated on a fixed timing basis when more than one non-null tone command is available in the dial buffer, and tones are generated on a continuous basis when only one non-null tone command is available in the dial buffer.

### BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1 shows the relevant portion of a conventional digital telephone device with a DSP including a DTMF generator.

Fig. 2 shows a process of generating DTMF tone signals in a conventional digital telephone device utilizing a DSP including a DTMF generator shown in Fig. 1.

Fig 3. shows a digital telephone device including a DSP with instruction buffer according to the principles of the present invention.

Fig. 4. shows the process of the routines in the controller in the digital telephone device of Fig. 3.

Fig. 5. shows the process of the routines for adding DTMF signal instructions to the buffer in the DSP in the digital telephone device of Fig. 3.

Fig. 6. shows the process of the routines for processing instructions in the buffer according to timing requirements in the DSP in the digital telephone device of Fig. 3.

#### **DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS**

The present invention implements a circular dial buffer in appropriate random access memory (RAM) accessible by the DSP (e.g., 16 or 32 bytes minimum) for the purpose of storing and dialing out DTMF digits. Although the DSP can use default digit/pause timings consistent with speed dial techniques, the processor (e.g., microcontroller) is able to customize such parameters to suit the needs of the particular application.

To the processor, the DSP appears to behave much like an off-the-shelf stand alone touch tone dialer, with the exception that the DSP does not have access to a keypad input. Instead, the manual timing associated with keypad input is simulated by the processor in commands to the DSP. Thus, instead of inputting rows and columns or other information relating to button activation on a keypad to input touch tone digits, the principles of the present invention utilize DSP commands sent

from the processor to the DSP to mimic manual activation of keys being pressed and released.

Thus, in accordance with the principles of the present invention, the processor in a processor/DSP telephony system is therefore no longer required to send precisely timed start/stop commands at precise intervals for directing the timing of the DTMF generator implemented in the DSP. Instead, touch tone digit commands may be sent by the processor to the circular dial buffer in the DSP as fast as the processor-to-DSP interface will permit.

As implemented in the disclosed embodiment, a DTMF tone generator can be implemented utilizing hardware already present in most digital telephone devices, e.g. a controller and a DSP including a DTMF generator, albeit without requiring the controller to monitor and calculate the timing of the DTMF transmissions from the DSP. Accordingly, the present invention provides for the generation of DTMF tone signals from a DSP either based on pre-programmed timing parameters for automatic dialing, but also in accordance with mimicked keypad activity transmitted from the controller to the DSP to affect a true DTMF dialer in the DSP.

Fig. 3 shows the relevant portion of a digital telephone device **300** including a controller **314** and a DSP **301**. Of course, either processor **314**, **301** may be any suitable type processor, e.g., a microcontroller, microprocessor, or digital signal processor.

The controller **314** in Fig. 3 is relieved of the duties of controlling timing of the output of DTMF tone signals, but instead transmits mimicked keypad signals to the DSP **301**. The controller **314** need only provide the DSP **301** with data corresponding to one or more DTMF tone signals which are to be generated: the DSP **301** handles the responsibility for the timing both for the length of each output DTMF tone signal as well as the length between each DTMF tone signal. If a current location of a circular dial buffer is filled with a non-null entry, DTMF



generation is performed as if in direct response to communication from a manual keypad. If the current location of the circular dial buffer is not filled, i.e., contains a null entry, the DTMF generation maintains the state of the last instruction.

5           The DSP circular dial buffer maintains a series of touch tone digit data transmitted from the controller **314** to the DSP **301** at any suitable timing. Because the DSP **301** is responsible for the timing of the generated DTMF tone signals between multiple digit information contained in the circular dial buffer, the specific speed and transfer  
10 mechanism used between the controller **314** and the DSP **301** is unimportant. For instance, a serial or parallel communication between the DSP **301** and the controller **314** may be utilized.

          The DSP **301** further includes a timer **304** which, under the direction of the DSP **301**, drives the timing of the generated DTMF tone  
15 signals when there is more than one tone digit contained in the circular dial buffer. In the disclosed embodiment, tone digits are read from the tone digit buffer **302** and output to the DTMF generator on a relatively fixed periodic basis, as controlled by the timer **304**. While Fig. 3 shows a switch mechanism between the controller **314** and the DTMF tone  
20 generator **303**, this is for explanation purposes only.

          The tone digit buffer **302** in the disclosed embodiment has a fixed length, e.g., 32 bytes. Moreover, in the disclosed embodiment, the tone digit buffer **302** is circular in that it forms a continual first-in, first-out (FIFO) type buffer. Although the controller **314** may write a maximum of,  
25 e.g., 32 tone digits into the tone digit buffer **302**, as tone digits are generated and completed, freed-up locations in the tone digit buffer **302** may be rewritten to by the controller **314** to queue up additional DTMF tone signals for generation by the DTMF tone generator **303** of the DSP **301**.

Fig. 4 shows one embodiment of a tone digit buffer **302** in more detail.

In particular, the tone digit buffer **302** includes rotating or circular slots which are continually directed to the DTMF generator **303** based on a circular addressing scheme, and timing established by the timer **304**. For instance, every 100 milliseconds (mS) as determined by the timer **304**, the next slot in the tone digit buffer **302** may be presented to the DTMF tone generator **303**, to provide relatively fixed and reliable length and spacing for each DTMF tone signal for automatic dialing.

Importantly, the circular dial buffer implements suitable commands interpreted by the DTMF generator **303** in the DSP **301** to allow emulation of a response to a manual keypad input directly to the DSP **301**.

For instance, besides the identity of pre-defined tone digits, the circular dial buffer may include an MF\_EMPTY, MF\_KEY or MF\_OFF command from the controller **314** to the DSP **301**. These particular command names are arbitrary: any particular command name may be utilized within the principles of the present invention.

The MF\_EMPTY command represents an empty tone digit location in the circular dial buffer. The circular dial buffer is initialized with an MF\_EMPTY command in each location, e.g., in each of the 32 locations.

The MF\_KEY command represents a single key press, mimicking an activation (and continued activation or depression) of a particular key on a key pad.

The MF\_OFF command represents a mimicked key release relating to a previous MF\_KEY command.

Preferably, the commands or digits are each unique such that the data written into the circular dial buffer alone is sufficient for the DSP **301** to interpret whether the digit represents a particular key, or

whether the digit represents a particular command (i.e., MF\_EMPTY or MF\_OFF used to mimic manual key pad information input to the DSP 301.

The principles of the present invention are embodied in the following example process.

5           In particular, the exemplary process is made up of two parts. The first part is the scanning of DTMF dialing commands and insertion of desired tone digits into the circular dial buffer in the DSP 301. This is a low priority background task requiring only that the interface between the controller 314 and the DSP 301 be serviced at least once every, e.g., 100  
10       milliseconds (mS) to guarantee that any incoming tone digits are processed and inserted in the circular dial buffer before the circular dial buffer is exhausted.

Step 1) The DSP circular dial buffer is initialized with MF\_EMPTY digits each representing an empty buffer. As digits are  
15       "pressed" (i.e., as control commands from the controller 314 are transmitted to the DSP 301 mimicking a key activation), the locations in the circular dial buffer containing MF\_EMPTY digits are overwritten with the appropriate new digit.

Step 2) During mimicked manual dialing, the controller 314  
20       will write two commands into the circular dial buffer: an MF\_KEY command or key representing a single key press, and an MF\_OFF command representing a key release.

Step 3) During automatic speed dialing, the controller 314  
25       will send a series of successive MF\_KEY commands (digits) representing the desired digits, terminated with an MF\_OFF command.

Step 4) The received MF\_KEY commands are inserted into the circular dial buffer, and the insert position pointer is incremented to point at the next available insertion location in the dial buffer.

Step 5) MF\_OFF commands, representing a key release, are inserted into the circular dial buffer, and the insert position pointer is left unchanged.

As a rule, MF\_KEY and MF\_OFF commands can overwrite only MF\_EMPTY and MF\_OFF commands. A buffer full condition with respect to the circular dial buffer is indicated when the next available insertion location in the circular dial buffer is occupied by an MF\_KEY digit.

The second part of the process is the dialing of digits to the telephone line by the DSP 301. This is a high priority foreground task which is preferably executed within an interval timer interrupt service routine with a repetition rate faster than 0.5 mS.

Step A) The dialer algorithm monitors the circular dial buffer for the presence of MF\_KEY and MF\_OFF commands.

Step B) Once an MF\_KEY command is found, the DTMF generator 303 is loaded with the desired DTMF parameters, and turned ON to output the desired tone. In the disclosed embodiment, a flag is set to indicate that the DTMF generator 303 is ON, and the digit timer is loaded with the appropriate digit duration. The dialed digit command in the circular dial buffer is replaced with an MF\_EMPTY command, and the dial position pointer is incremented to point at the next available dial location in the dial buffer.

Step C) No further action need be taken until such time that the digit time expires.

Step D) If an MF\_EMPTY command is found in the next location of the circular dial buffer, then the DTMF generator 303 is left unchanged. This is the case for mimicked manual, continuous DTMF generation.

Step E) The absence of an MF\_EMPTY command in the next location of the circular dial buffer indicates that the DTMF generator

**303** has to be turned OFF prior to dialing the next digit. Thus, the DTMF generator flag is cleared and the digit timer is loaded with the appropriate pause duration.

Step F) No further action need be taken until such time that  
5 the digit time expires.

Step G) If the next available digit in the circular dial buffer is an MF\_OFF command, then the digit is replaced with an MF\_EMPTY command in the circular dial buffer, and the dial position pointer is incremented to point at the next available location in the circular dial  
10 buffer. A response is preferably sent to the controller **314** to indicate the end of dialing.

Thus, the controller **314** starts by sending the first MF\_KEY command representing the desired first tone digit. A late response from the DSP **301** to accept the digit at this stage is not critical for DTMF  
15 timing. Timing only becomes an issue once the first digit is accepted and the DTMF generator **303** is started. Therefore, so long as the controller **314** keeps sending digit commands to the DSP **301** fast enough to prevent the circular dial buffer from becoming empty, the DSP dialer will be able to maintain the correct, automated DTMF timing for auto-dialing.  
20 Once the controller **314** stops sending commands and the dial buffer becomes empty, the dialer will leave the DTMF generator **303** at its last state prior to when the circular dial buffer becomes empty. Thus, if the last command was an MF\_KEY command, then the DTMF generator **303** is left ON representing or mimicking a key of a keypad being pressed for  
25 an extended amount of time. A subsequent mimicked key release is affected by an MF\_OFF command being sent to the DSP **301** from the controller **314**, and as a result the DTMF generator **303** stopped.

The particular speed at which the tone digit buffer **302** rotates or circulates may be variable, and can be programmed by the DSP  
30 **301** (or initialized by the controller **314**). Moreover, every other slot is

known to correspond to a null or silent period, and thus the timing can have two aspects: one corresponding to even and one corresponding to odd slot locations. Thus, for instance, the DTMF tone signals can be generated for a longer period of time than the silent periods therebetween, or vice versa.

Similarly, since a silent period is typically desired between each DTMF tone, it can be automatically inserted after each slot in the tone digit buffer **302** to eliminate the need for null locations, e.g., locations **402, 404** shown in Fig. 4.

One feature of the present invention is that the controller **314** may write tone digits corresponding to separate DTMF tone signals at its own pace, independent of the generation timing and spacing of the DTMF tone signals. For instance, if the tone digit buffer **302** is emptied before all desired tone digits are written to by the controller **314**, then a 'position' in the circular buffer is left as a null or no DTMF signal.

The DTMF tone generator **303** in the disclosed embodiment can be enabled and disabled such that when enabled, it is fed a continuous stream of tone digit data as timed by the timer **304** until disabled.

When transferring tone digit data to the tone digit buffer **302** of the DSP **301**, the controller **314** preferably utilizes conventional handshaking to ensure a reliable communication of the tone digit data. However, blind data transfers may be acceptable in certain applications wherein the controller **314** assumes that once communicated to the DSP **301**, that the tone digits are placed in the proper locations in the tone digit buffer **302**.

Preferably the tone digit buffer **302** is of suitable length to accept all tone digit data written at any one time by the controller **314**. However, an acknowledgment routine may be implemented as between the controller **314** and the DSP **301** to coordinate a delay in transferring

tone digit data from the controller **314** to the DSP **301** in the event that the tone digit buffer **302** becomes temporarily full. However, these delays will be minimal because of the circular nature of the tone digit buffer **302**, i.e., a slot is freed up every, e.g., 100 mS, based on the timing in the timer

5    **304.**

          The present invention is particularly useful in applications requiring a long sequence of DTMF tone signals. For instance, in conventional systems wherein the controller **314** is responsible for the generation timing of the DTMF tone signals, long tone sequences would

10    be extremely taxing on the other tasks being performed by the controller **314** and would suffer significantly from timing variances caused by jumping between tasks. In contrast, the present invention provides consistent timing no matter what the length of the tone sequence, and does not affect the performance of other tasks, particularly those

15    operating on the controller **314**.

          The present invention allows a DSP to become a true DTMF dialer, offering advantageous features such as reduced DSP memory usage when compared with conventional speed dial solutions, savings of external dialer costs, timing independence of the controller, simplified

20    controller code, programmable digit parameters, seamless automatic and/or mimicked manual dialing capabilities, chain dialing and continuous DTMF dialing capabilities.

          While the invention has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to

25    make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.